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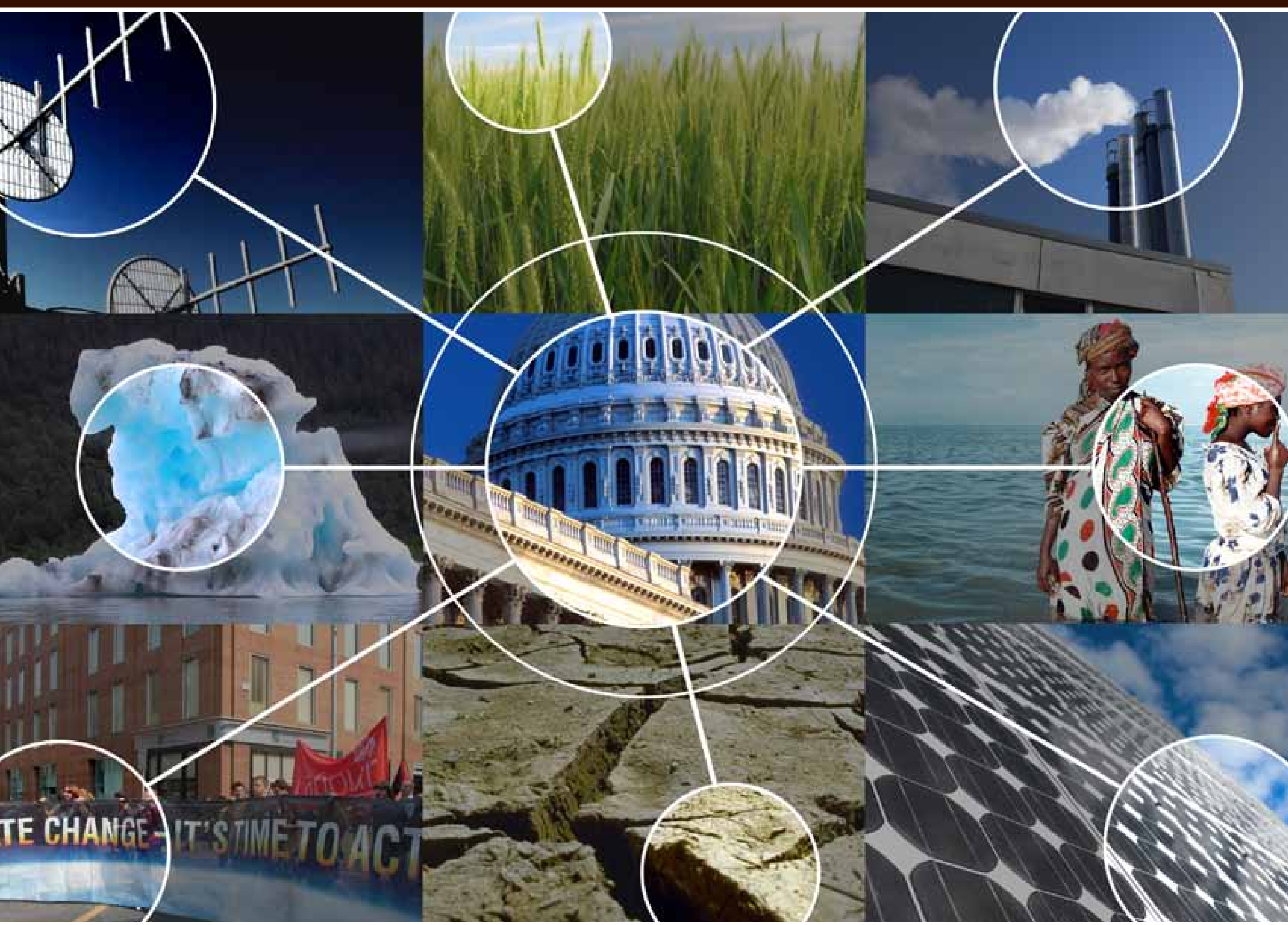
SCIENCE POLICY ASSESSMENT AND RESEARCH ON CLIMATE

Conducting research, education and outreach to improve the ability of climate science policies to support climate-related decision making

USABLE SCIENCE:

A HANDBOOK FOR SCIENCE POLICY DECISION MAKERS



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SCIENCE POLICY ASSESSMENT AND RESEARCH ON CLIMATE

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USABLE SCIENCE: A HANDBOOK FOR SCIENCE POLICY DECISION MAKERS
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USABLE SCIENCE: A HANDBOOK FOR SCIENCE POLICY DECISION MAKERS

1 SCIENCE FOR DECISION MAKING

WHO IS THIS GUIDE FOR?

We aim these ideas at anyone involved in the process of designing, directing, or implementing research -- those who decide what research gets done and whose needs the research is intended to serve. These ideas may be helpful to individuals and groups in a variety of different settings, including professionals in federal agencies, Congressional staffers, scientists managing a lab or sitting on a panel at the National Research Council, or managers at a foundation with a science focus.

INTRODUCTION

In 2010 the US federal government will have spent more than $150 billion on research and development. What gets done with that enormous sum has important implications for the wide variety of problems facing our society today and in the years to come. Important decisions on challenges like national defense, environmental change, rapid urbanization, and public health rely on scientific knowledge to inform them. Given the complexity and the significance of such challenges, how can science funders effectively orient a vast research enterprise to make real progress toward desired social goals?

This guide is about the challenge of producing usable science, which we define as science that meets the changing needs of decision makers. Producing usable science requires smart choices about the support for and management of science. We refer to the people making these choices as “science-policy decision makers.”

As anyone involved with federal research and development (R&D) knows, making choices about what science to do, and how to do it, is complicated. No single person or organization decides how to allocate resources to various research areas, and no single set of criteria can determine the best course of action. We cannot offer a simple explanation of how to navigate the complex politics of this process. However, the findings from our five-year, National Science Foundation-supported research program suggest some useful approaches to thinking about science management and science funding. We have condensed them in this short guide, along with some specific examples from across the federal government, in the hopes that science decision makers will find this an accessible and meaningful contribution to their work.

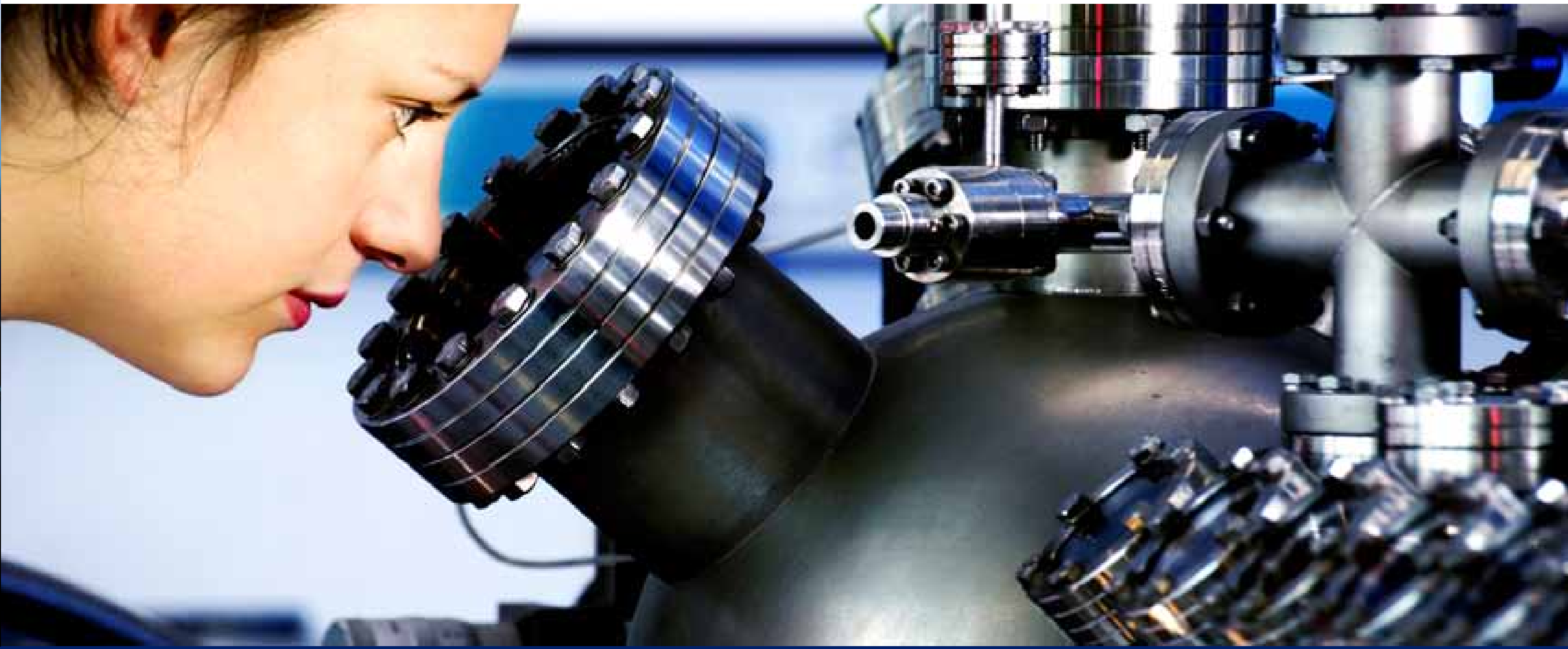
SCIENCE FOR DECISION MAKING

Our research has focused on the problem of reconciling the needs of potential science users ("demand") with the "supply" of scientific information (more on these terms in Section 3). Through interviews, workshops, and analyses, we have examined the interactions between these two sides of the equation, and the ways in which people seek to reconcile them with varying degrees of success. The results have implications for the practice of science and for the management of science programs by federal agencies and other actors.

The fundamental conclusion of our work: Science best meets the needs of decision makers when those needs are considered throughout the institutions, policies, and processes that comprise the scientific enterprise.

Our fundamental recommendation: criteria for verifying the ***usability*** of scientific results, and specific accounts of the ***outcomes*** which R&D programs aim to fulfill, are crucial to managing science for decision making.

Our research has focused largely on climate change and other environmental research programs, but our conclusions and recommendations apply to a much greater cross-section of federal R&D. Indeed, we feel that engagement across this landscape is crucial to improving the usefulness of science. Facilitating this will be an important part of our own work as we move forward.



2 MYTHS THAT PREVENT PROGRESS

COMMON MISPERCEPTIONS

In our research we encounter four common but misleading assumptions about science-policy decision making. These assumptions have been and continue to be important drivers of the policies, practices, and institutions involved with science policy decision making. **Not everyone holds these assumptions, but any individual in this arena must contend with them.**

MYTH #1: USABLE SCIENCE = APPLIED RESEARCH

Many see the generation of usable science as synonymous with doing applied research. However, dealing with real world problems often requires advances in fundamental knowledge, or basic research. For example, much of the basic physical science research that the U.S. government funded after World War II was aimed at the military and political problems of the Cold War. **A commitment to usable science for decision making does not imply the abandonment of basic research.**

MYTH #2: THE BENEFITS OF SCIENCE ARE COMPLETELY UNPREDICTABLE

Science is often described as an unpredictable process, in which the most important discoveries are serendipitous. Though new knowledge may lead down unexpected paths, it is also true that the history of science in the past sixty years is one of powerful linkages between research priorities and social goals, especially in the area of technological advance. Indeed, most federal science—including basic research—is justified in terms of particular desired benefits. We cannot pursue all possible research directions, so we need to be skillful in deciding which ones deserve attention and resources. This is both a matter of reality, in that choices will be made, and experience, which tells us that some choices have better results than others. **There is no reason to avoid thoughtful planning in pursuit of explicit goals.**

MYTH #3: MORE KNOWLEDGE IS ALWAYS USEFUL

We often assume that solving a difficult problem requires more research, but not all knowledge is equally useful, and technical information makes up just one part of a larger system in which problems occur. It is important to consider the role of evolving knowledge, and the extent to which ***more*** of it is necessarily better. **Sometimes we have adequate knowledge to address a problem, and additional research may not be the best approach.** And, if we do want better information, we can ask "better in what way?" before we decide what kind of research is most appropriate to the task.

MYTH #4: DECISION MAKERS BENEFIT FROM SCIENCE AT THE END OF THE RESEARCH PROCESS

As part of controversial issues, one commonly hears debate over whether the science is "settled." But the scientific process almost never comes to final conclusions and often involves irreducible uncertainties. There is thus a tendency for scientists to want to wait until the end of a project or until all scientific uncertainties are resolved to engage decision makers. The problem is that without engagement early on, the research path taken may be irrelevant to decision maker needs. Moreover, there is valuable and useful knowledge to be imparted to decision makers despite uncertainties. **For decision makers to benefit from science, they must be involved in the research process early and often.**

MYTHS THAT PREVENT PROGRESS

MOVING BEYOND THE MYTHS

When individuals and institutions embrace the myths outlined above, the scope of options that science-policy decision makers consider is reduced. By setting aside some of these common misconceptions, and adopting a set of guidelines and concepts that ensure a strong connection between research and improved societal outcomes, science policy decision makers can become more open, creative, and effective in pursuing usable science. This guide begins to outline principles that can help foster decisions about science that more reliably respond to societal goals, while making a case for further engagement to build on this effort.

We have divided the remainder of this guide into three sections. Section 3 presents a conceptual framework for thinking about science-policy decision making. Section 4 begins a discussion of how to use the framework in the real world. This section recognizes that many competing demands, and a variety of other obstacles, present challenges to science policy decision makers who wish to try a new way of doing things. Section 5 makes the case for continued engagement among science policy decision makers to share experiences and learn about best practices.

3 SUPPLY OF AND DEMAND FOR SCIENCE

RECONCILING SUPPLY AND DEMAND

We suggest conceptualizing the problem of managing science for decision making in terms of the relationship between the "supply" of science information, and the "demand" for usable information. The notion of supply and demand and their relationship is borrowed from economics, where supply and demand are strongly interrelated, interdependent, and co-determined. In science policy, however, explicit demand for information by potential users outside of the scientific community is rarely a strong determinant of the supply of scientific information. **Ensuring that the supply of scientific information is in line with the needs of decision makers requires attentive management. There is no "invisible hand."**

RESPONDING TO THE PROBLEM: HAZARDS RESEARCH

The costs of future disasters are projected to increase due to more frequent and intense extreme events such as storms and floods. But this is only explains part of expected growth in disaster losses. Damage from extreme events is largely determined by patterns of human development, e.g. the trillions of dollars' worth of beachfront housing and infrastructure. Development involves choices made every day in regions that experience extreme events, and these choices influence the nature of future disasters.

If policy makers wish to address the escalating costs of disasters then it is important to understand how alternative actions will influence future damages. Policy debates on climate change tend to focus on energy policies, but increasingly acknowledge that adaptation must also be a part of the discussion, especially with regard to disasters.

In one application of this concept, we examined the sensitivity of future losses to changes in climate and changes in patterns of future development. Instead of predicting changes in climate, development, or future disaster losses, we assessed what factors are likely to be most responsible for any potential changes in those phenomena across a wide range of assumptions. We hoped to enable decision makers to identify beneficial policy actions despite uncertainties.

Our research found that, under any plausible scenario of climate change, the most important factors in the growing costs of disasters are patterns of development – what people build, and where. Studies indicate that for every dollar in damages in 2000, we should expect $4.60 in damages in 2050, or an increase of $3.60. Half of this increase is due to development, whereas only a sixth is directly due to the most serious projected changes in climate. The overwhelming importance of societal change in driving future losses is consistent across all scenarios of climate change, development, and damage projections. Thus any research program intended to address the problem of escalating disaster losses should address and inform the problems of social change and coastal development, and not just the physical impacts of a changing climate. This suggests that science policy decision makers should revise their definition of the problem, and the associated research priorities in order to address what most contributes to the problem.

SUPPLY OF AND DEMAND FOR SCIENCE

CHARACTERIZING SUPPLY

> **more knowledge is not always *useful.***

Awareness of the factors that steer science in one direction or another facilitates clearer thinking about research prioritization. How did some programs or particular issues come to win priority over others? Which inputs ***should*** inform one's choice of research pathways? How might those inputs change over time? How should one balance the many important priorities espoused by an agency or program in order to produce usable science?

> **what *kind* of knowledge is most helpful?**

When science-policy decision makers are aware of the range of research currently under way to address a given problem, they may leverage areas of overlap, fill important gaps in existing knowledge, and generally direct agendas to where they are most needed. **However, characterizing supply requires an assessment of information needs relative to a *decision context*, as opposed to a discipline or field.**

Scientific research inevitably leads to more questions, expanding the possibilities for research. But the progress of knowledge within a particular scientific discipline (such as hydrology or ecology) is not necessarily linked to real-world problems (such as drought or species loss). For example, an incremental advance in the skill of a groundwater model may be of interest to hydrologists in the field; but that advance may not translate into any additional utility for water managers and others dealing with water scarcity issues. **Producing science for decision making requires recognizing the differences between supporting research valued by the discipline itself, and supporting research for the purpose of solving a particular problem.** Every research program will approach these trade-offs differently. When managers explicitly recognize this tension in their decisions about research funding, they are better positioned to make decisions that lead to useful knowledge.

A CASE FOR ORGANIZATIONAL CHANGE: NOAA AND HURRICANE RESEARCH

US hurricane research largely focuses on prediction. Indeed, the FY2009 NOAA budget includes a four-fold increase for hurricane prediction research - to $17 million, of which only $350,000 funds research into human dimensions and implications. Accordingly, atmospheric scientists continue to develop ever better predictions of hurricane trajectories and intensity. Yet Hurricane Katrina remains a stark reminder that accurate prediction itself is not enough to prevent losses. While agencies like FEMA refocus to be more prepared for future extreme events, the research enterprise continues to give prediction research its highest priority rather than shift its focus, as the USGS did, to decision-maker needs as a means of reducing vulnerability **(See: *Organizational Change in the US Geological Survey*).**

Budgets for hurricane research are limited, and by emphasizing prediction as the primary means of reducing vulnerability, the need to understand the social and political network through which society responds to hurricanes is deemphasized. Prediction has proven valuable for hurricane response, but insufficient for vulnerability reduction. Societal factors and demographic patterns remain important causal factors for losses, as we have recently seen in the case of Hurricane Katrina **(See: *Responding to the Problem: Hazards Research*).**

SUPPLY OF AND DEMAND FOR SCIENCE

UNDERSTANDING DEMAND

A farmer making a decision about what crops to plant, and when, may benefit from a seasonal forecast. However, his ability to use and benefit from forecast information depends on his social and economic resources, his tolerance for risk, and his trust in those delivering the information, in addition to the climatological realities of the region. The forecast information needs of a subsistence farmer may differ widely from those of a large farming corporation.

> **with an understanding of the decision making problem, we *can* improve the benefits of research.**

The demand for information is rarely represented by a single perspective. The diversity of potential users may result in a cacophony of voices, each with a unique view of decision making problems and their solutions and unique information needs. For this reason, **an all-inclusive approach to working with users could be as ineffectual as ignoring user needs altogether**. There is no single process or set of criteria for determining the best way to incorporate user needs into a research program. However, based on our own studies of programs that have undertaken user engagement, we identify three considerations that play a prominent role in assessing demand:

- carefully define (or identify) the broad ***societal*** problem a research program seeks to address;

ORGANIZATIONAL CHANGE IN THE US GEOLOGICAL SURVEY

In the mid-1990s, the US Geological Survey (USGS) faced intense scrutiny from Congress, accusations of irrelevance to societal problems, and threats of extinction. At the same time, the USGS's large-scale earthquake prediction program, the Parkfield Earthquake Experiment, was widely deemed a failure. This, combined with mounting discontent with the traditionally isolated, basic science approach of many of its scholars led the USGS to reconsider its approach. The mission of minimizing the loss of life and property during natural disasters remained the same, but instead of relying on better prediction to minimize losses, the USGS shifted its focus to the effects of, and responses to earthquakes. This required a reprioritization, and encouraged scholars to identify and actively work with users.

Consequently, USGS scientists have actively developed relationships with the users of their information – e.g. state departments of transportation, building engineers, utilities, and local governments – and have shaped their research agendas based in part on those lasting partnerships. In lieu of prediction, once a primary value driving their science portfolio, a large percentage of the agency budget now focuses on the decisions these users must make to reduce vulnerability. For example, in cooperation with lifeline operators (electricity, water, power) and the California Department of Transportation (Cal Trans), USGS scholars develop shake maps – assessments of the intensity of ground shaking around an earthquake site. They integrate these maps with Cal Trans's assessment of its infrastructure, and together with Cal Trans, send out automatic alerts when an earthquake hits. Owing to these developments and this new focus, earthquake research benefits from the buy-in, input, and understanding of its intended users . These USGS researchers actively work with users, and shape their research priorities to meet decision maker needs.

SUPPLY OF AND DEMAND FOR SCIENCE

- define specific categories or groups of users that should be involved; and
- identify the outcomes that would represent progress from the users' perspective.

Each of these considerations depends on the others. For example, one might want to identify users who can help to define the decision-making problem before describing desired outcomes. Alternatively, identifying a manageably narrow group of users might require careful definition of the problem in advance. **In practice, this will almost certainly amount to a process of continual adjustment as knowledge advances, user needs change, and understandings of the problem evolve.** In addition, some elements of the process may be beyond the control of a decision maker if, for example, they are specified as part of the legislative process. Decisions regarding the approach to creating usable science depend largely on the organizational context (e.g. mission, goals) of the research program, the resources available, and the context of the research to be undertaken.

WHEN EVERYONE'S A STAKEHOLDER ...

No program has the resources to involve every region and sector of society in the kinds of interactions necessary for setting responsive research priorities. In recent years, the US Global Change Research Program (USGCRP) has been criticized for its failure to make scientific knowledge useful to decision makers (a major part of its mandate). Certainly, a major part of the problem is lack of resources.

But such efforts have also come up short because of a failure to identify, pursue, and build into the program relationships with stakeholders. For USGCRP, potential users have effectively been "anyone and everyone." With no clear idea of who they are targeting, and where they can make the most progress with their limited resources, the USGCRP's approach has been haphazard and passive, inviting participation without demanding the investment and mutual understanding needed to make meaningful progress.

CASE STUDIES IN ASSESSING DEMAND

1. Priority-setting Workshops

The Agricultural Research Service's (ARS) Global Change research program convenes periodic workshops with scientists and users including those from federal agencies, agricultural nonprofits, and the agricultural producer community.

These workshops help the USDA set research priorities for the next planning cycle based in part on what customers want from research. Workshops of this kind not only directly inform priorities, but can also help to establish enduring lines of communication with potential end users, and move science closer to meeting demand. These workshops are typical of each of the ARS's National Research Programs. Usually the Program Leaders, along with the rest of the program team consisting of three to four ARS scientists, are in charge of the workshops. The process runs on a five year cycle and features both backward-looking and forward-looking assessments of programmatic research. A common process will include a survey of the research that the program supplies and is proposing to supply, a needs assessment, during which the ARS invites users to discuss their informational requirements, and a discussion between users and suppliers on how researchers can work to meet those requirements.

SUPPLY OF AND DEMAND FOR SCIENCE

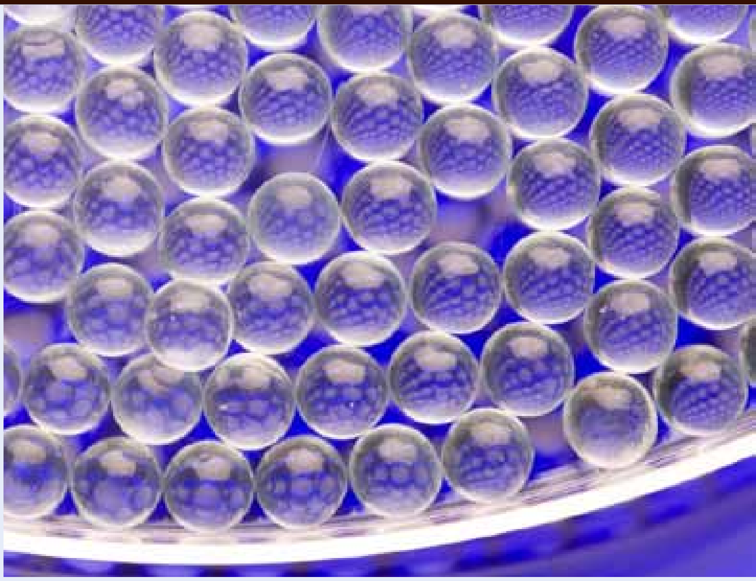
CASE STUDIES IN ASSESSING DEMAND CONTINUED

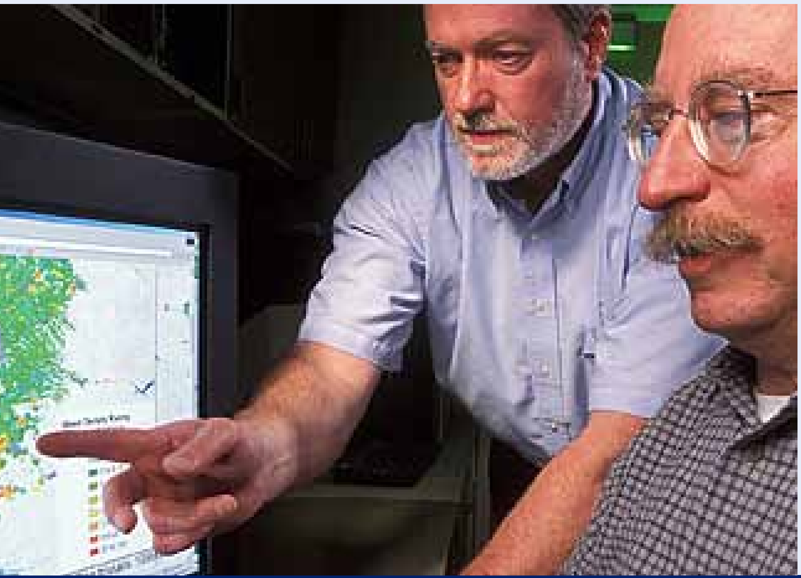
2. Test Runs and Feedbacks

The Naval Research Laboratory's Meteorology Division works to enhance the value of meteorological tools that the Navy uses. These tools can range from short term regional weather forecasts to more specified applications, such as those that let officers in the Middle East track dust storms. When making a more advanced model, or when adding a new feature intended to aid decision makers, NRL staff will often test an early version of the new technology with users in the Naval fleet by simply e-mailing them a link to the new model and asking for feedback to help assess the added value of new developments.

Agricultural Research Service scientists also work directly with users to test and refine products such as new agricultural management strategies or decision tools for farmers. Through test runs coordinated with users, researchers thus learn about the value of their work in a real world environment from actual users.

A mandate from the Bush Administration charged the ARS with developing mechanisms for accounting for agricultural carbon sequestration. In recent years, scientists in the ARS Global Change National Program have developed CQESTR, a computer model with the purpose of predicting carbon dioxide sequestration in agricultural land under different soil types, crops, and management regimes. In order for this model to actually help farmers in making decisions, however, they will need to see it as useful and understand how they will benefit from using it.





3. Review Protocols for Assessing the Impact of Research

As a director of the National Institute of Standards and Technology's (NIST) Material Science and Engineering Laboratory (MSEL), Richard Kayser worked at the helm of a research venture with the mission of meeting the materials science needs of industry. For the MSEL lab, and specifically, for the director, a significant challenge lies in creating an actual impact for those in the materials industry.

Kayser's protocol for assessing proposed research projects considers both the impact of the research and the risk of failure. Assessment of impact includes both the promised level of impact as well as how well that impact is articulated. Risk includes both risk of technical failure and risk of failed technology transfer. The highest ranked proposals have a low risk and high impact that is convincingly articulated. Assessing the risk of technology transfer reflects NIST's commitment to getting its products into the hands of industrial and academic users. Research is only usable to the extent that potential users are capable of adopting it.

Other decision makers have implemented or considered similar strategies. A consideration of impact during prioritization and evaluation could encourage projects that are more likely to address need. Thus, those proposals that are either better able to articulate eventual usability, or that might lead to a high impact (even if risks are moderate) become more likely to go forward. Scientific or technical excellence cannot stand alone as a criterion of usability or value.

Agronomist George Mueller-Warrant and hydrologist Jerry Whittaker look at alternative locations for conservation practices in the Calapooia River watershed. (Credit: Photo by Peggy Greb)

SUPPLY OF AND DEMAND FOR SCIENCE

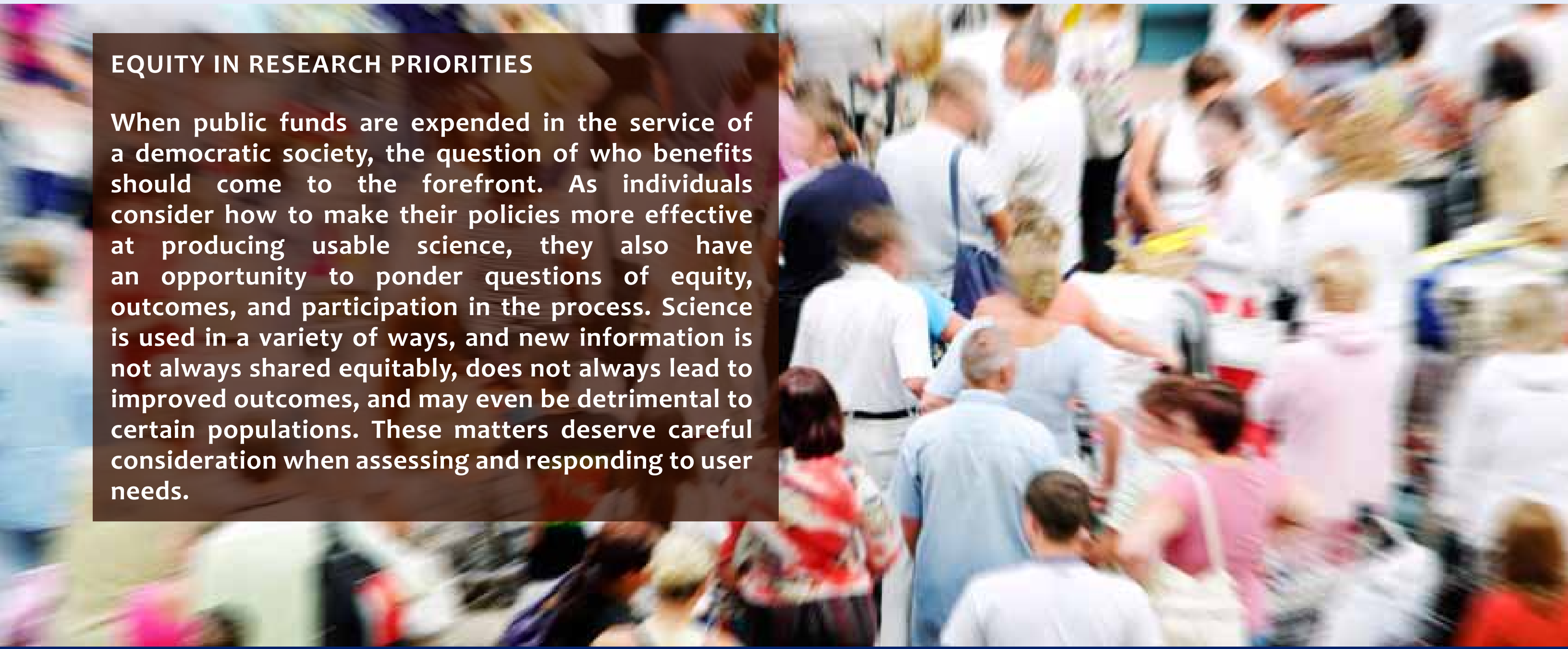
CASE STUDIES IN ASSESSING DEMAND CONTINUED

4. Probing the Options: Heilmeier Questions

A series of appropriate questions can also be used as a general guide for making sure science policy makers are addressing the need to reconcile supply and demand. One example is the Heilmeier Questions, originated by George Heilmeier, a former director of DARPA and vice president at Texas Instruments:

1. What is the problem?
   Why is it hard?
2. How is it solved today?
   By whom?
3. What is the new technical idea?
   Why can we succeed now?
4. Why should your institution do this?
5. What is the impact if successful?
   Who would care?
6. How will you measure progress?
7. How much money?
   How long will it take?

The questions offer a way to address potential impacts of research. While the first three address the technical problem, and technical impact, the other four speak to issues of demand and fit to broader institutional goals. Finally, questions 6 and 7 address logistical research issues that affect implementation.



EQUITY IN RESEARCH PRIORITIES

When public funds are expended in the service of a democratic society, the question of who benefits should come to the forefront. As individuals consider how to make their policies more effective at producing usable science, they also have an opportunity to ponder questions of equity, outcomes, and participation in the process. Science is used in a variety of ways, and new information is not always shared equitably, does not always lead to improved outcomes, and may even be detrimental to certain populations. These matters deserve careful consideration when assessing and responding to user needs.

SUPPLY OF AND DEMAND FOR SCIENCE

RECONCILING SUPPLY AND DEMAND

We have condensed the conceptual problem of reconciling the supply and demand of scientific information into a simple graphic called the "Missed Opportunity Matrix." **All too often, the two simple questions proffered in the matrix do not play a role in the decision making of science managers.** We believe that asking these questions in the normal course of writing requests for proposals, reviewing grant proposals, and evaluating results, involves a shift in attitude that can benefit users and researchers alike.

In working to reconcile supply and demand, science policy decision makers must:

- relate the mission, goals, and results of research to specific, on-the-ground problems;
- establish ongoing processes to engage with, and seek to understand, the needs of users;
- incorporate the needs of users into the practice of science funding and science management; and
- test and evaluate the results of research intended for use.

		Demand: Can User Benefit from Research?	
		YES	NO
Supply: Is Relevant Information Produced?	NO	Resarch agendas may be inappropriate	Non-user
	YES	Empowered users taking advantage of well-deployed research capabilities	Disenfranchized or marginalized users, institutional constraints, or other obstacles prevent information use

The Missed Opportunities Matrix highlights circumstances (shaded boxes) in which supply and demand are poorly matched.

These are not incremental steps of a linear process; they are ongoing, complementary components of supporting research that helps people to make better decisions. **Reconciling the supply and demand of scientific information requires more than a single workshop or focus group; it must be built into the institutions that make decisions about science priorities.**

CONGRESS AND USABLE SCIENCE

Congress has supported science generously over the last half-century, but not without occasional calls for more accountability. Science is not an entitlement program, and has always needed justification as a national priority. Justifications have ranged over time, including issues such as workforce preparedness, economic competitiveness, technological advantage, military superiority, and so on. But these debates tend to focus on broad national trends, and assume that science is useful regardless of the makeup of our nation's science portfolio. Whatever the merit of these arguments, they rarely propose that science funding programs reconcile supply and demand of information. For example, the Global Change Research Act of 1990, which required funded research to generate information useful to policy makers, did not specify the process for ensuring this outcome.

Nonetheless, calls for science to be more relevant to specific policy problems such as climate change, nanotechnology, and global health are becoming more prevalent. Congressional members and their staff can be quite influential in shaping this policy debate and ultimate national position toward usable science. Over the years, members of Congress have run hearings, introduced legislation, and initiated changes in science policy such as the broader impacts criterion for NSF proposals, an issue championed by Barbara Mikulski, and the integration of social, environmental, and ethical concerns into nanotechnology research priorities. **(See: *Leadership in Congress: George Brown*).**

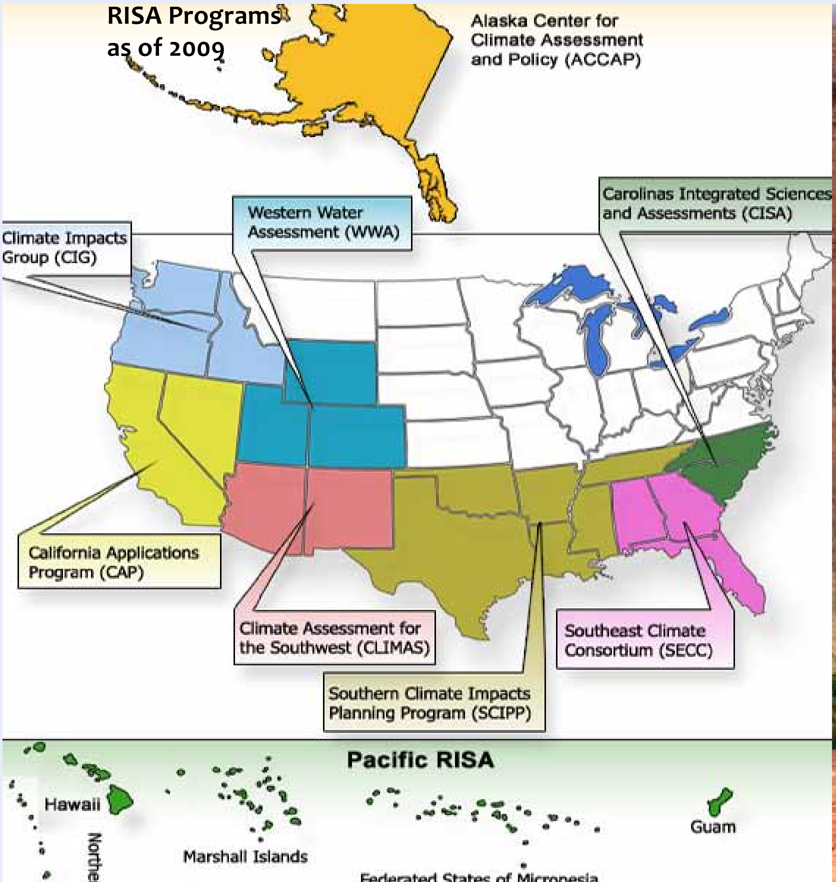
SUPPLY OF AND DEMAND FOR SCIENCE

RISA PROGRAMS

NOAA's Regional Integrated Sciences and Assessments (RISA) programs use a variety of techniques to reconcile their scientific research efforts with their various users' information demands, ranging from the informal to the formal. All of the RISAs engage in frequent communication with their stakeholders, starting their conversations early. These events involve one-on-one meetings, group meetings, or conversations over the phone. Informal communication provides a forum for both sides to clearly identify and understand the nature of the problem they seek to resolve, and to understand the unique contexts of potential solutions. Through such informal, iterative meetings, RISA researchers were able to adjust their own research objectives, provide existing information to stakeholders, or could producing information for which the users had no useful purpose. Moreover, these meetings created opportunities for both sides to develop trusting, mutually respectful relationships that facilitate future efforts.

The RISAs also engaged in more formal efforts to reconcile supply with demand. For example, one RISA program created and administered formal surveys to thoroughly test the effectiveness of the RISA's data and information products. Other surveys investigated how well decision makers understood the particular ways in which the data presented. The RISAs used these engagement opportunities to assess, adjust, initiate or abate individual research streams.

As part of the RISA program researchers and program managers work closely to reconcile the supply and demand of scientific information. The program was designed with deliberate attention to the importance of understanding user needs and the usability of scientific results. Rather than relying on a traditional model of issuing a request for proposals – in which the request itself is the product of scientific advisory bodies – a new process was designed to require investigators to consult with stakeholders, and develop research agendas specific to the climate-related problems of a region. In addition to a high degree of interaction between the program managers and prospective research teams, managers worked hard to broaden participation in review and evaluation of individual RISAs, which has helped to widen the view of "excellence" espoused by the Program.



4 MAKING IT HAPPEN

OPPORTUNITIES FOR INNOVATION

Changing the processes of funding and managing science is not easy. In the course of our research we have identified a variety of challenges common to many organizations that support science for decision making. We present those below, followed by a preliminary list of opportunities for programmatic innovation, drawn from our interactions with program managers from across the federal government. As we argue in the final section, program managers could build on this list by coming together to share experiences and learn about new approaches.

CHALLENGES

Supporting Researchers: Program managers wanting to encourage reconciliation of supply and demand need to be aware of the challenges this poses for grant recipients. In the case of university research, for example, these challenges require thinking creatively about how to reorient incentives in an academic system that traditionally emphasizes publications, citations, grant-writing, patenting, and other metrics of scholarly merit instead of relationship-building and decision support.

Funding Cycles: Research agendas are often geared to relatively short lifecycles of three to five years. This timeline does not always match the needs or expectations of users. The normal duration of a grant may be too short to establish trusting relationships among producers of information and potential users. As one individual involved with emergency planning and management in the Pacific said, "Don't even bother bringing your briefcase for the first two years... it takes that long before the stakeholders will trust you."

In many cases normal funding cycles may be too slow to respond to user needs. There are exceptions, however. In the anthrax attacks after September 11, decision makers urgently required new research on testing and monitoring for anthrax. While the National Institute of Standards and Technology's (NIST) normal research programs would not have addressed this need, they adapted to this timeline and successfully met the demand. It is important to understand the need for and create flexible structures that can be nimble in the face of changing problems.

Evaluation and Performance Measures: Evaluation of research often focuses on quantitative measures such as the number and citation impact of publications that emerge from a research grant. Such performance measures discourage and impede pursuit of outcomes that, while qualitative rather than quantitative, relate more strongly to the mission and goals of a program than traditional measures.

Justifications used to secure support should provide the basis for developing criteria for program evaluation and should extend to program metrics and accountability. Too often, considerations of use presented in the process of securing support for a program are forgotten once the funds arrive.

Organizations: The culture and inertia of an organization tend to favor the existing way of doing things. While not necessarily a bad thing, this constrains entrepreneurship. Disciplinary stovepipes do not lend themselves to addressing interdisciplinary, complex, societal issues. Individuals seeking to motivate more usable science must work to break down these divisions, or look for creative ways to organize in spite of existing structures. This means striving for a supportive environment where managers can take risks and be innovative in their development of programs.

OPPORTUNITIES

There are many opportunities to enhance the creation of usable science and there have been many successes in the U.S. research enterprise, including within the climate science community. Many individuals make decisions that influence science programs, from Congressional staff, to Office of Management and Budget (OMB) examiners, to agency program managers, to members of NRC panels proposing priorities for research. Science-policy decision makers, reflecting institutional, political, and other constraints, play an essential role in shaping programs and their outcomes. Leverage points in this shaping process include writing requests for proposals or announcements of opportunity, setting budget priorities or examining budgets during the agency pass-back process, conducting or testifying at hearings, writing legislation, contributing to expert reports, reviewing proposals, and making funding decisions on individual grants. Individuals involved in any of these at any level of the science policy process have an opportunity to make decisions that improve the usability of science.

Mandate and Mission: The mandate and mission driving an agency or program can be quite broad, leaving room for interpretation and opportunities for new approaches. In almost all cases, federally funded science ***does have a mandate to address particular classes of problems***, whether in defense, energy, safety, health, or national competitiveness. Moreover, such problems are often articulated in terms of desired social outcomes.

Metrics: Science is changing. Interdisciplinary efforts are far more common, and "broader impacts" or evidence of use of science in society are becoming a more common goal. This sea change may accommodate new metrics commensurate with the task of creating usable science.

Review and Advisory Mechanisms: Through peer review and expert advice, the prioritization and decision-making process for science has remained largely within the scientific community. A science manager might consider expanding review and advisory processes to include a wider cross-section of experts, including potential users, who can assess usability and relevance along with scholarly merit. Both NOAA (RISA and Sectoral Applications Research Program [SARP]) and NASA Applied Sciences have experimented with this in some of their programs.

Science-policy decision makers, especially those involved with distributing resources, have a unique opportunity to foster dialogue among existing constituencies through workshops, town halls at science and professional conferences, hearings, and so on. Often these are high value activities taken on in addition to core responsibilities. Program managers can work to demonstrate the benefits of such endeavors, while looking for ways to make them a part of job descriptions, performance evaluations, and other metrics.

MAKING IT HAPPEN

LEADERSHIP IN AGENCIES: MIKE HALL

J. Michael (Mike) Hall demonstrates how one person can encourage the production of usable science throughout an agency and a research initiative. Hall was the Director of the Climate and Global Change Program at the National Oceanic and Atmospheric Administration, a Federal agency charged with understanding changes in the environment to support decision making. In the grand scheme of things, the program's budget was relatively small ($70M annually out of a $2B Federal investment), but the influence of the program was far-reaching because of the outlook and practices that Hall instilled in his employees. Hall himself was a systems thinker, looking at the big picture and encouraging others to do so. Many who worked for him were inspired by this larger vision, and an office atmosphere was created where civil service in the government was exciting, effective, and ground-breaking. Hall listened to everyone, and remained open and curious about new ideas his entire career, while remaining grounded in strategic thinking and a practical approach. He encouraged risk-taking, creating an environment where it was "ok to screw up," especially if that was done in the context of stretching and attempting something new and innovative.

Hall was fond of saying "sometimes you just have to break some pottery" in order to move forward with a different direction. He assembled a team that spanned across many different disciplines, and looked specifically for people who could think broadly and who came from different backgrounds, both within government and from academia. Most importantly, Hall empowered his employees to seize opportunity, do what needed to be done to address the important goals, and not shy away from larger challenges. For Hall, the bigger the challenge the better, and he did everything within his ability to support and protect his employees to reach for those challenges as well. For example, he created the space within a primarily physical sciences program to fund social sciences, and create new institutions and models to link science to society. Without his support, it is doubtful that employees would have felt comfortable challenging assumptions and moving in non-traditional directions.

Several innovative programs emerged from his leadership that still stand as model programs in the area of climate and service to society: the Tropical Ocean Global Atmosphere program, the International Research Institute for Climate and Society, the Regional Integrated Sciences and Assessment Program, the Human Dimensions Program (now the Sectoral Applications Research Program). These initiatives have all led to profound advances in science, along with valuable discoveries of how science is or is not used in decision making, while fostering entire communities of new scholars and science policy decision makers. Hall was awarded the Waldo E. Smith Medal in 2004 from the American Geophysical Union in recognition of "his vision, his innovations in program management, his nurturing of young talent, and his deeply held values that have so advanced science in the service of humanity." **(See: *Leadership in Congress: George Brown*).**

MAKING IT HAPPEN

CONGRESS AND NSF'S "BROADER IMPACTS" CRITERION

In 1997, influenced by the demand for Federal agencies to produce "demonstrable results" expressed in the Government Performance and Results Act of 1993, the National Science Foundation (NSF) created what became known as the second or "broader impacts" criterion (BIC) for the assessment of grant proposals. Henceforth, in addition to assessing proposals in terms of their intellectual or scientific merit, proposers and reviewers of grant proposals were asked to answer the question: "What are the broader impacts of the proposed activity?"

Because of its emphasis on impacts beyond those of simply producing more knowledge, the introduction of BIC promoted reflection on whether a research program was responding effectively to a real social need. But over the last decade, BIC has increasingly been interpreted rather narrowly as encouraging the promotion of science for the sake of science. For instance, BIC is now most often satisfied by including public education and outreach activities, with little consideration for whether these are really demanded by the social context.

How, then, might BIC be addressed in ways that enhance the supply of scientific knowledge that responds to a real societal demand rather than simply trying to create a demand for a knowledge supply that scientists themselves want to create? In 2007 Congress proposed its own answer to this question in the form of the America COMPETES Act, which explicitly ties BIC to the promotion of Responsible Conduct of Research (RCR) activities, such as mentoring post-doctoral researchers and instructing undergraduate and graduate students in the ethics of research. Such an answer, of course, interprets the question of the supply and demand of scientific knowledge as a question concerning the ***quality*** rather than the ***quantity*** of knowledge production. Instead of using BIC just to promote more science, Congress is expressing the demand for scientists to think in terms of producing ***better*** science.

This raises the question of what one means by 'better science.' Answers to this question will vary with the particular context, but the context of climate science presents a salient example. Although billions have been spent on increasing the quantity of our knowledge regarding climate change, not enough attention has been paid to the quality of that knowledge in terms of its usability by decision makers. Interpreted broadly, ***BIC might encourage climate scientists applying for NSF grants to conduct research that will respond to a specific need in addition to justifying the research on educational grounds alone***.

MAKING IT HAPPEN

LEADERSHIP IN CONGRESS: GEORGE BROWN

Congressman Brown was simultaneously a champion of science in the U.S. and a provocateur, challenging science to examine its role in serving society. Even before his election as Chair of the House Committee on Science, Space and Technology, Brown urged scientists to think hard about their role in society, and how their research might be useful, though it often put him at odds with Nobel-prize winning scientists. He did not accept that scientific research was automatically useful. Nor did Brown accept the premise that the application of science was uniformly beneficial to society—he recognized that negative consequences were also possible and that part of science's responsibility was in assessing the implications of science and technology and their appropriate role in society. A man of impeccable integrity, Brown did not shy away from speaking the truth as he saw it, no matter the constituency, and he consistently opposed research he viewed as contributing to bad outcomes, such as breeder reactors and anti-satellite weapons.

Brown was instrumental in creating links between politics and science and technology, including the Office of Technology Assessment and the Office of Science and Technology Policy, which was formed to advise the President on matters of science and technology and their effects. Among his many accomplishments, Brown led the establishment of the National Climate Program through passage of the National Climate Program Act of 1978. Some of the pioneering elements of that act have become an essential part of climate science today: assessments of the effect of climate on natural and social systems, conducting both basic and applied research to understand natural processes and the social and political implications of climate change, and global monitoring and forecasting. These career achievements reflect Brown's constant belief that scientists had to accept accountability for the social outcomes they helped to create. Through his tireless leadership, love of science, and passion for social justice, Brown enlarged the boundaries on which science engaged societal values, paving the way for a new vision of usable science. **(See: *Congress and Usable Science*).**

A NEW TAKE ON RISK-TAKING

Risk-taking is a widely embraced value in agencies funding basic research. Program managers in agencies such as the NSF, DOE, DOD, and NIST, often emphasize that major scientific advance requires a willingness to fund ideas that offer the combination of high risk and high potential payoff.

But the definition of risky research needs expansion. Decision makers should not just fund high risk, high reward scientific ideas, they should also apply this norm to the incentive structures that govern research. This means exploring new kinds of collaboration, communication, and metrics. It could involve bringing in a completely foreign discipline to work on the problem, or requiring a different balance between formal research and "outreach" activities in the budget proposal. **(See: *RISA Programs*).**

5 BUILDING COMMUNITY

In addition to facilitating progress toward desired outcomes, reconciling supply and demand can greatly expand the community of individuals who recognize, trust, and become champions for both a program and the science it funds. Reconciling supply and demand can also lead in unexpected and exciting new directions for both science and social action. Some of NOAA's RISA programs, for example, have established a basis for extensive and lasting interdisciplinary and service-oriented research programs that have gained the attention and support of state and local governments.

In this short publication we have tried to identify some issues, opportunities, and frameworks that may be shared among science managers and other individuals who wish to generate usable science, even if they work in vastly different organizations.

But there are likely many more.

Coming together to share experiences and best practices across a wide range of problem areas, from health and environment to homeland security and social justice, may prove mutually beneficial. Issues such as appropriate metrics, what works and what doesn't, how to involve stakeholders, and the role of champions may translate across cultures and contexts.

As we carry this research forward we will continue to engage with science managers, and attempt to build a critical mass of practitioners taking a creative approach to reconciling supply and demand. An effort to look for common ties also has benefits for creating a sense of community, fostering programmatic innovation, saving time, and helping to make science more useful.

BUILDING COMMUNITY

The Science Policy Assessment and Research on Climate (SPARC) program is a joint project of the University of Colorado's Center for Science and Technology Policy Research and the Arizona State University's Consortium for Science, Policy, & Outcomes that was funded under NSF's Decision Making Under Uncertainty (DMUU) program. More information on:

SPARC:
http://sciencepolicy.colorado.edu/sparc/

DMUU:
http://www.nsf.gov/news/news_summ.jsp?cntn_id=100447

Center for Science and Technology Policy Research:
http://sciencepolicy.colorado.edu

Consortium For Science, Policy & Outcomes:
http://www.cspo.org

References to this handbook are available online:
http://sciencepolicy.colorado.edu/sparc/outreach/sparc_handbook

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USABLE SCIENCE:
A HANDBOOK FOR SCIENCE POLICY DECISION MAKERS

SPARC

http://sciencepolicy.colorado.edu/sparc/outreach/sparc_handbook